It will be seen that this more general inquiry entirely justifies the prior statement[1] that the metallic lines are thickest in stars increasing their temperature, and the hydrogen lines thickest in stars decreasing their temperature, in other words, on the opposite arms of the temperature curve. I have already stated a possible explanation.[2]

It will be observed that, so far, I have not been able to find stellar spectra on the downward side corresponding to those of γ Argus and ζ Orionis; but it is more than probable that near the apex of the curve only a small change, will be observed; their default, therefore, is of less consequence than it might have been.

The same remark applies to α Cygni and Sirius; but here it is certain that the differences in the relative intensities of the gaseous and enhanced lines will be considerable, judging from what happens above and below the heat stages represented by them.

The stars used in the discussion give us very definite results, showing that the various chemical forms are introduced at six very distinct heat levels.

The Temperature Ranges.

I next proceed to make some remarks upon the series of facts now for the first time brought together; it must, however, be borne in mind that all the chemical elements and all parts of the spectrum have not yet been included in the survey.

(1) Hydrogen appears throughout both series of stars from top to bottom. Proto-magnesium and proto-calcium follow suit very nearly; but the highest intensity of the former is reached at the stage represented by α Cygni, and of the latter at the solar temperature represented by α Tauri and Arcturus.

(2) With the above exceptions all the chemical forms so far traced are relatively short-lived.

This is the first important differentiation. In the light of (1) we are justified in assuming that the substances in (2) would be visible in the stellar reversing layers if they were there.

(3) In the stars of higher temperatures we deal generally with gases. Below the stages represented by β Orionis and γ Lyræ we deal with proto-metals and metals, hydrogen being the only exception.

(4) The proto-metals make their appearance at about the same heat-level at which the gases (with carbon), always excepting hydrogen, begin to die out.

This is the second important differentiation. It is interesting to notice the distinct difference of behaviour of carbon and silicium in the descending series; the former goes through the same stages as oxygen and nitrogen, the latter behaves like the proto-metals.

(5) With the exception of iron the metals, as contradistinguished from the proto-metals, only make their appearance in stars at and below the heat-level of Sirius.

This is the third important differentiation. It is accompanied with a notable *diminution* of hydrogen and proto-magnesium, and with an *increase* of proto-calcium; indeed, the latter seems generally to vary inversely with the hydrogen.

In all these changes we seem to be brought into presence of successive polymerisations due to reduction of temperature. Of the origin of proto-magnesium and proto-calcium the stars as yet tell us nothing; but it is difficult to believe that the earliest forms of the other metals are not built up of some of the constituents of the heat ranges represented by those between γ Argus and α Crucis.

The question arises whether the order of visibility at reduced temperatures now indicated does not explain the absence of proto-hydrogen, oxygen, and nitrogen from the spectra of the sun and nebulæ; the metals present in, and the absence of quartz from, meteorites, and the similarity of the gaseous products obtained from meteorites and metals, native and other, in vacuo at high temperatures.

NORMAN LOCKYER.

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[1] *Proc. Roy. Soc.*, vol. lxi. p, 182.

[2] *Proc. Roy. Soc.*, vol. lxi. p. 183.

THE INSTINCTS OF WASPS AS A PROBLEM IN EVOLUTION.[1]

THIS work has been looked forward to with the deepest interest by all naturalists who are familiar with Dr. and Mrs. Peckham's observations upon the courtship of the spiders, and who were aware that this long-continued and laborious research had been undertaken by them. The observations and conclusions of M. Fabre upon the instincts of the solitary wasps have been so often quoted, and have formed the foundation of so large a superstructure of theory, that it became of the highest importance that they should be repeated by other naturalists. The late George Romanes and many other writers on evolution have always looked upon these observations as the strongest of all arguments for a Lamarckian instead of a Darwinian interpretation of instinct. Thus Romanes wrote in "Mental Evolution in Animals": "Several species of the Hymenoptera display what I think may be justly deemed the most remarkable instincts in the world. These consist in stinging spiders, insects, and caterpillars in their chief nerve centres, in consequence of which the victims are not killed outright, but rendered motionless; they are then conveyed to a burrow previously formed by the *Sphex*, and, continuing to live in their paralysed condition for several weeks, are at last available as food for the larvæ when they are hatched. Of course the extraordinary fact which stands to be explained is that of the precise anatomical, not to say physiological knowledge, which appears to be displayed by the insect in stinging only the nerve centres of its prey" (quoted by the authors on pp. 221, 222). A still more imaginative description is also quoted (on pp. 220, 221) from Eimer, who says: "This is one of the most marvellous instincts that exist; since the wasp operates on various larvæ with nervous systems of various forms, she must effect the paralysis in various ways, and even apart from this, she makes a physiological experiment which is far in advance of the knowledge of man. . . . It may be suggested that the wasp only paralysed the larvæ in order to carry them more easily; but even if this were the case, she must, since she now invariably acts in this way, have drawn a conclusion by deductive reasoning. In this case it is absolutely impossible that the animal has arrived at its habit otherwise than by reflection upon the facts of experience." The authors truly say of these remarks, and the rest of the quotation from Eimer: "One can hardly be expected to take such statements seriously, since it is certain that the writer has no knowledge of the life-histories of these insects." Eimer and Romanes were both quoting from Fabre, and, relying upon his inferences even more fully than upon his observations, they both held that a Lamarckian interpretation is inevitable. Such instincts, they maintained, can only have arisen by the inheritance of the results of intelligent observation. In order thoroughly to test the foundation upon which such far-reaching conclusions have been built, Dr. and Mrs. Peckham have carefully observed all the species of solitary wasps which they could find in their beautiful summer home, with Dr. C. A. Leuthstrom, on Pine Lake, Wisconsin. As in the case of other insect orders, these Hymenoptera have a wonderfully familiar look to an

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[1] "On the Instincts and Habits of the Solitary Wasps." By George W. Peckham and Elizabeth G. Peckham. Wisconsin Geological and Natural History Survey. *Bulletin* No. 2. Scientific Series No. 1. (Madison, Wis.: published by the State, 1898.)

English zoologist, the same genera and closely similar species occurring in very large numbers. The present writer has had the great privilege, in the summer of 1897, of seeing Dr. and Mrs. Peckham at their work, and of discussing with them many of their results.

The habits of one or more species of the following genera were studied with the utmost care, and are described in Chapters i.-xiv.: *Ammophila*, *Sphex*, *Rhopalum*, *Stigmus*, *Crabro*, *Salius*, *Aporus*, *Bembex*, *Oxybelus*, *Trypoxylon*, *Astata*, *Diodontus*, *Cerceris*, *Philanthus*, *Pompilus*, *Agenia*, *Tachytes*, *Lyroda*, *Priononyx*, *Chlorion*, *Harpactopus*, *Pelopaeus*.

It will be admitted that the careful study of species in these twenty-two genera constitutes a serious amount of evidence which entitles the authors' conclusions to the most careful consideration.

Chapter xv. contains a *résumé* of the most interesting observations and conclusions in Paul Marchal's important monograph on *Cerceris ornata*. Chapter xvi. is devoted to the sense of direction; xvii. to the stinging habit in wasps; while Chapter xviii. states the conclusions upon the instinct and intelligence of wasps, which the authors believe to be justified by their observations.

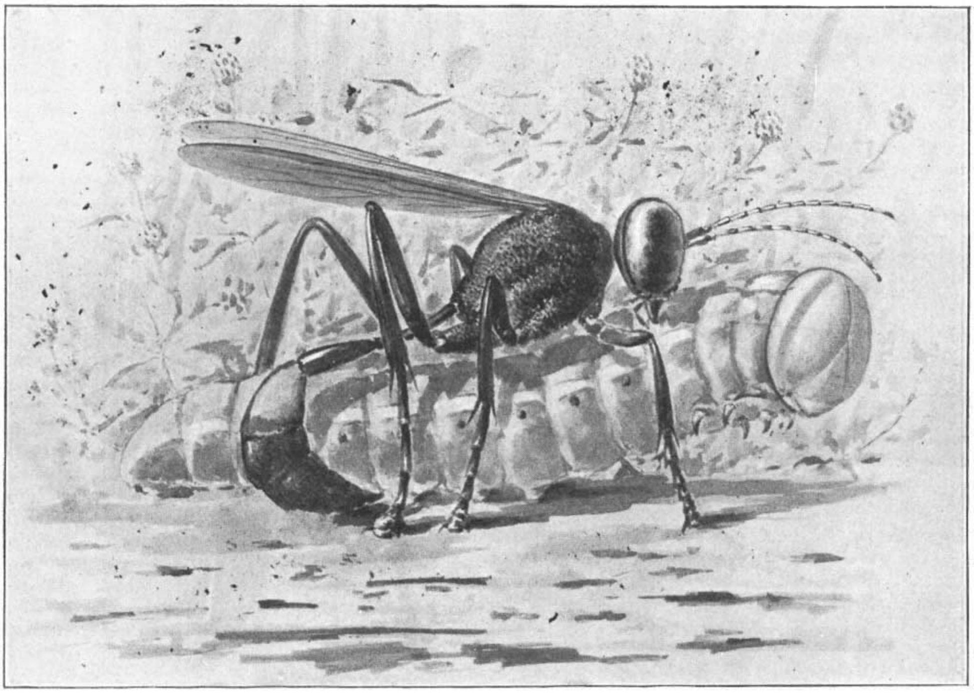

FIG. 1.—*Ammophila urnaria*, stinging caterpillar.

The fourteen plates are skilfully drawn by J. H. Emerton, who illustrated the authors' works on spiders. Plates I. and II. contain excellent coloured illustrations of thirteen of the species whose habits are described; the remaining plates are uncoloured. Plates III., IV. and V. deal with the habits of *Ammophila urnaria*, the most interesting of the species which were studied. Fig. 1 is a reproduction of Plate IV. (p. 11), and shows the manner in which *Ammophila* stings the caterpillars, which it stores up in the burrow in which it lays its egg. After much patient watching the whole process was observed from beginning to end on three occasions. On the first of these the caterpillar was first stung on the ventral surface between the third and fourth segments. "From this instant there was a complete cessation of movement on the part of the unfortunate caterpillar," which was then stung between the third and the second, and between the second and the first segments. The wasp then circled in the air above the caterpillar, "and then, descending, seized it again, further back this time, and with great deliberation and nicety of action gave it four more stings, beginning between the ninth and tenth segments and progressing backward." The second wasp also stung the third, second, and first segments in order; and then she went on to sting the fourth, fifth, sixth and seventh, but stopped at this point, proceeding, however, to bite the neck of the caterpillar in a very thorough manner (malaxation). In the third example the wasp gave one sting between the third and fourth segment, and then spent a long time in biting the neck. In this case, however, the caterpillar had been placed by the observers in the way of the wasp, and she seemed rather indifferent to it.

I have quoted these observations at some length because a closely allied European wasp (*A. hirsuta*) seems more than any other species to have afforded the evidence relied upon by Fabre and those who have followed him. By the study of but nine wasps of the same genus, and fifteen caterpillars, the American naturalists have shown that the immense superstructure which has been raised on so small a foundation is in large part due to a fertile imagination. So far from the assumed perfection and accuracy with which every detail is supposed to be repeated, the instinct is shown to be excessively variable. The frequently quoted conclusions that the object of the sting is to reduce the larva to helplessness and yet to keep it in a fresh condition, that a dead larva would be unsuitable food and an active one a danger to the offspring of the wasp—all these conclusions are entirely disposed of by a few carefully specially directed observations. These show that the larva rapidly dies in a large proportion of cases and yet affords excellent food, and that it may remain sufficiently uninjured to wriggle continuously without stimulation, or to move violently when bitten by the larva of the wasp.

The fifth plate (p. 23) is reproduced in Fig. 2, and shows *Ammophila urnaria* using a stone to pound down the earth with which the entrance to the burrow is covered. This very interesting observation is confirmed by the study of *Ammophila Yarrowi* in Western Kansas by S. W. Williston.

The remaining plates show the appearance of many other species which were studied, and also include representations of their burrows, prey, and several very interesting "locality studies" made by wasps of many species before they leave a freshly dug burrow to seek for prey. The representation of these complex movements in the neighbourhood of the burrow strongly supports the authors' conclusions in favour of the dominant importance of the sense of sight in these Hymenoptera—conclusions which they also support by many other observations and experiments.

The following activities or performances are regarded as truly instinctive: stinging, the methods of attack, capture and carriage of prey peculiar to each species, the kind of prey selected, the general style and situation of the nest, the form of cocoon.

If the exigencies of space permitted, it would be of great interest to discuss many of the points raised in this valuable research. It is only possible on the present occasion to point to certain observations which indicate that the action of the wasp's poison on the ganglionic centres may be through the hæmolymph and not necessarily direct. If this be so, it disposes of the necessity for any great precision in the locality of the sting. A puncture *anywhere* would produce effect, although probably more rapidly and completely if made in the neighbourhood of a ganglion. Further observations on this point are greatly needed, including a long series of experiments in which wasps of many kinds are held in the forceps and made to sting their natural prey in various parts of the body. The question of malaxation suggests another most interesting field of inquiry; in fact, the great value of the work depends as much upon its suggestive and inspiring spirit, as upon the full record of discovery which it contains.

The type is clear and good, although the quality of the paper leaves much to be desired. There are a few obvious misprints and erroneous references which will soon be detected by the reader.

The volume ends with the following paragraph—and the reader will admit that very solid grounds are given for the conclusions. "The general impression that remains with us as a result of our study of these activities, is that their complexity and perfection have been greatly overestimated. We have found them in all stages of development and are convinced that they have passed through many degrees, from the simple to the complex, by the action of natural selection. Indeed, we find in them beautiful examples of the survival of the fittest."

E. B. P.

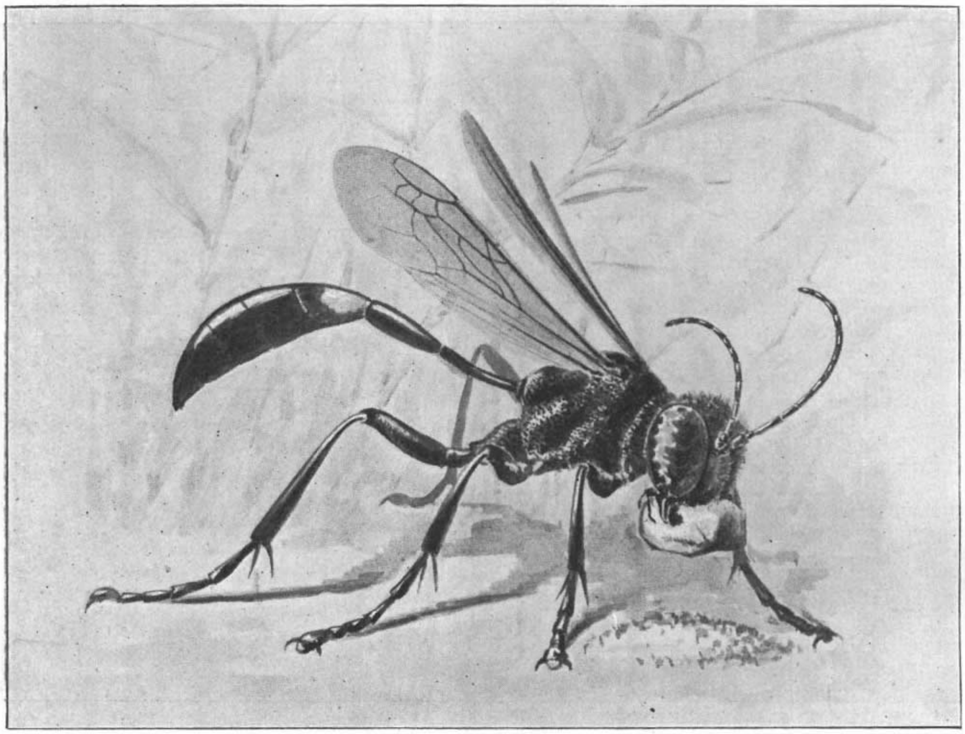

FIG. 2.—*Ammophila urnaria* using stone to pound down earth over nest.

SIR JOHN STRUTHERS, M.D., LL.D.

ON February 24 death removed from amongst us the *doyen* of the professors and teachers of anatomy in Scotland.

John Struthers was born at Dunfermline in 1823. He began to study medicine in the University of Edinburgh in 1841, and obtained the degree of Doctor of Medicine in 1845, when he wrote his thesis "On the Physiology and Physiological Anatomy of the Muscles and Nerves of the Eyeballs, and on the Theory of their Derangement